STATEMENT OF WORK

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0. INTRODUCTION

0.1. Overview

This Full and Open Competition, 5-year contract supports a wide array of geodynamic, geomagnetic, geophysical, and atmospheric investigations of solar system bodies such as the Earth, Venus, Mars, and Mercury. Among the requirements for these investigations are instrument development; software development and maintenance; data collection, archiving and dissemination; scientific data analysis, modeling and interpretation; reports and presentations of scientific results; public outreach and education; and associated technical and administrative work.

The contractor shall provide support to investigators associated with current programs and projects such as GRACE, the Ocean Surface Topography Mission, the Interdisciplinary Studies in Earth Science, ICESat, and future missions outlined in the roadmap of Earth-science missions defined the National Academy of Science Decadal Survey, such as SWOT, DESDynI, ICESat-2, GPSRO, and GRACE Follow-On. The contractor shall provide support to investigators involved in analysis of space geodetic data (SLR, DORIS, and GNSS), used for geodetic analysis, precision orbit determination, and the determination and maintenance of the terrestrial reference frame. The contractor shall provide support to investigators involved with LAGEOS-1, LAGEOS-2, Starlette, Stella, LARETS, LARES, Earth Positioning satellites such as GPS, Galileo, and GLONASS; Earth altimetry satellites such as TOPEX/Poseidon, Jason-1, Jason-2, GEOSAT, GEOSAT-Follow-On (GFO-1), GFO-2, CryoSat-2; planetary spacecraft such as Mars Global Surveyor, Mars Odyssey, Lunar Reconnaissance Orbiter, the Mars Reconnaissance Orbiter, MESSENGER, and MAVEN. The contractor shall provide support for data systems such as the CDDIS.

For the purposes of organization, this Statement of Work (SOW) is divided into four main sections. The work is categorized according to whether the main emphasis lies in one of the following four areas: **1.)** Geodynamic, Geomagnetic, and Planetary Studies; **2.)** Altimetry and Remote Sensing; **3.)** Software Development and Maintenance; and **4.)** Data Centers. The Table of Contents shows the further subdivisions of these sections.

Work accomplished on this support services contract shall include support in the areas described above and in the Statement of Work, as defined by the contracting officer, CO, through the Task Ordering Procedure Clause of this Contract. Each order shall include specifications, schedules, deliverables, and performance criteria.

The contractor, in accordance with this SOW, shall provide all necessary resources, including personnel, facilities, equipment, and materials, unless otherwise provided by the government, in order to fulfill the work requirements. Supporting documentation will be prepared and delivered as specified in the contract.

The contractor shall deliver required documentation in accordance with the terms of the Contract.

0.2 Types of Work

The following type of work are supported by this contract:

SCIENCE

Scientific Instrument Support

Support the design, development, fabrication, testing, integration, and calibration of instruments and readout systems for in-house use or field deployment. Ancillary to this effort are site surveys; field engineering data collection; equipment installation; data analysis; and documentation. For existing instruments, hardware and equipment support is required for design, development, installation, testing, checkout and support for interfacing new optical, mechanical, electrical, and electronic assemblies. Monitoring the status of equipment used in laboratory and field experiments is required. In addition, the contractor will support operation and management of engineering and computing facilities; laboratory and field deployment of hardware and software; field observations and flight support; instrument modification and equipment refurbishment; and personal computer systems including installation of hardware and software, user training and troubleshooting problems involving hardware, software, or networks.

Instrument Modeling and Simulation

The two primary objectives are to:

-Develop and communicate an understanding of the scientific impact of variations in instrument performance with time, as well as the impact of changes in either instrument specifications or spacecraft/aircraft/ground truth requirements.

-Provide spectral, spatial, and radiometric modeling and scene simulation capability, and support algorithm development, testing and analysis. The models will allow for characterization of ground targets, observing conditions, and the observing system. The model results and simulated data sets shall be used in the development and testing of calibration and masking algorithms.

Science Research Support

Support all phases of geophysical, geodynamic, geodetic, oceanic, atmospheric, and biospheric research from experiment concept and design, through data acquisition and reduction, to data analysis and modeling. This includes geodynamics and geophysics, specifically gravity and magnetism, topography, altimetry, geoid anomalies, planetary rotation, tides, crustal dynamics, and Earth’s core fluid motions. One of the objectives is to better understand the spectral, radiometric, and geometric characteristics of image data. This includes research of planetary radiation budgets; radiation transfer through the land, ocean, cryosphere, and atmosphere; soil moisture and forest and plant canopy modeling; land surface heat and water balance modeling; the role of aerosols, trace gases, and pollutants in the photochemistry of planetary atmospheres; thermal structure, dynamics and heat balance of the planetary atmospheres; dynamics and physical and chemical properties of the tropospheric and stratospheric constituents, and thermosphere properties; and global vegetation studies.

Support data analysis operations, which require computer programs encompassing such areas as pattern recognition, simulation of physical systems, parameter estimation, image data analysis, dynamic interaction with graphical displays, mathematical modeling of physical theories and associated numerical and scientific analyses, and data correlation studies using statistical techniques. This requires problem analysis and program implementation for both on-line data processing and on-demand processing via remote terminals. The support also requires development and implementation of data visualization and animation methods in order to provide increased understanding of the prediction capabilities for geophysical processes and parameters.

Support the mathematical analysis and computer implementation of techniques to perform such functions as radiative transfer and optical scattering analysis, image enhancement, noise removal, radiometric corrections, geometric corrections, registration, filtering and other transformations, pattern recognition, multivariate classification, and change detection of Earth resources and meteorological image data. Included will be conducting surveys or literature searches, gathering or generating related data, setting up and conducting tests, analysis of test results, producing reports of the investigation, recommending solutions and development, and implementing techniques to solve particular information extraction problems.

Scientific research support also includes:

-Coordination and support of measurement operations.

-Real-time and near real-time data acquisition and quick look displays.

-Prepare validated data product.

-Analysis, restructuring, modification, and recoding of software and algorithms for efficient use of mainframe computers and the workstation environment, depending on the need.

-Modeling of new measurement data and additional physical phenomena.

-Simulation of processes for studying environmental parameters and performing analysis and validation of physical parameters derived from existing ground, aircraft, and satellite observations.

-Optimization of numerical techniques.

-Extension of parameter estimation capability.

-Development and improvement of program user applications.

-Precision, bias, and error analysis shall accompany the data analysis, with appropriate software development to provide an operational correction capability.

ENGINEERING

Systems Engineering/Development

Support all phases of systems development and systems engineering. This includes all aspects of systems engineering such as requirements definition and analysis; conceptual and detail design; integration; hardware sizing and validation; the development of technical specifications; the development of automatic data processing equipment acquisition plans; configuration management; and the development and control of external interfaces including digital communication networks. Such support may include aspects of mechanical and electrical engineering along with aspects of the computer sciences. In support of the various kinds of scientific research being done, the contractor will provide the expertise to research, design, integrate and enhance technical systems consisting of hardware and software as required.

Engineering Support

Engineering support involves all aspects of the design, development, fabrication and verification of research instrumentation. Included in this support are the basic-engineering designs and analyses of an instrument, the drafting of component sections, the development of electronic components, assembly, field testing, and the evaluation and verification of acceptable performance of systems, subsystems and instrumentation when coupled with computer support. Equipment and instrument installation, maintenance, operation, modification, repair, upgrade, and transport will be required and sustained to assure mission success and maintain effective data collection capabilities. Spare parts will be maintained as required. Documentation of all engineering developments will accompany services. Required completion dates will be established, and milestone schedules will be developed, with sufficient detail to provide a clear understanding to the contractor and to the government of the status of each task, and the estimated hours to complete.

Mission Engineering Support

Support NASA's mission planning from the conceptual phase to prototype instrumentation to surface/aircraft/spacecraft deployment to data processing systems design, archive, and data distribution. Support is required for mission planning, independent verification and validation of software and hardware, scheduling, instrument control and coordination of activities for data gathering systems. Studies are required for instrument ground support equipment, data systems design, data handling facilities, computing system architecture, networks and communications, mass storage and archiving systems, transformation of observations into physical variables and generation of various data processing scenarios, and data cataloging and distribution systems. Further studies involve estimating data capture volume, Earth coverage, and data delay time for various real-time, near real-time and delayed applications. Included are plans for system design and trade-off considerations for converting raw data to scientifically meaningful products mapped to standard projections. Also included are plans for quality assurance, archiving and distribution of products.

FIELD MEASUREMENTS

The contractor shall aid in conceiving, planning, organizing, and conducting field campaigns to obtain data critical to the data analysis and modeling efforts being conducted within the Laboratory. Unexplained or wide variations in the results obtained during different segments of the experiment shall be investigated with software designed to pinpoint error sources.

COMPUTING

Computing Systems Management

Provide system management expertise which includes items such as: installing, updating, and testing new releases of manufacturer-supplied operating systems and commercial software packages; setting up authorization and accounting files and procedures; performing backups; setting up and monitoring computer security; performing the general maintenance functions required of system management; performing error analysis; monitoring and tailoring system performance; consulting and other activities that are required of the system management expertise function. Provide the full range of user services required to support a spectrum of scientific computer systems from small stand-alone systems to a networked large-scale supercomputing facility. This includes documentation, problem tracking and resolution, telephone assistance, software tailoring to meet user requirements, training, performance analysis of application packages, and other activities that are required to support central system activities.

Maintain and assure efficient operation of Laboratory computers and peripherals such as PC's, Macintosh's, and workstations. Assure that software is appropriately configured for high efficiency.

Algorithm Development

Develop and test algorithms, including algorithms for science data products, data and instrument characterization, calibration, utility masking, browsing, and product quality assessment. A theoretical basis for each algorithm shall be provided. The algorithms shall be integrated into a single system, implemented in a structured language, and tested to verify scientific utility. Deliverables are the algorithms, software, test datasets and their results, and documentation.

Scientific Data Processing

Support the design of efficient input/output and data packing/unpacking techniques; the application of total instrument calibration results to experiment data; data reformatting operations; handling and correlating satellite and detector housekeeping information required for data analysis; elimination of data overlap and merging of orbit/attitude data where necessary; applying the appropriate data reduction algorithms to process the raw initial data into final physical units; and implementing numerical algorithms as required.

Processing System Development

Design and develop systems for producing scientifically valid data. Known errors will be removed to improve accuracy by conducting appropriate software reviews and prototype tests. Provide programming guidelines that shall enable the users to produce routines, which utilize the services of the processing system. Provide coding guidelines for programmers. An iterative process of modifying software and returning modified code based on processing results shall be used to correct the system. An independent test team will be selected to conduct independent tests of the processing system. They shall develop a test plan, and tests specified in the plan shall test compliance with all system requirements. The test team shall also develop test data sets to exercise the individual software components of the system. Facilitate and run test cases, obtain test data sets as defined by the users, and assess results of test cases. Produce and evaluate quality control products for all aspects of the system. Develop prototypes of any advanced processing systems. The prototypes should allow for the exploration of concepts about the design of the integrated system. The prototypes shall also enable the users to test software in a processing environment. A significant portion of the early effort in this function may be focused on assembling test data sets for development, testing and validation. Software that will support ingesting, storing, browsing, and reading and writing these data sets shall be designed.

ADMINISTRATIVE SUPPORT

The contractor shall provide administrative support for meetings. This support includes the generation of presentations for the meetings and attending the meetings. Provide appropriate staff coverage of the meetings to answer questions and collect requests. Support includes preparing reports and/or position papers for the meetings and documenting the results of the meetings. Analyze and respond to plans, reports, status, etc.

Plan, develop, implement, and test telecommunications systems. Monitor performance, gather statistics, generate reports, evaluate performance, trouble-shoot, analyze and resolve problems in the area of networking systems.

Manage data resources, databases, and computer facilities. Maintain a computer-based formal project management system providing critical path and status information. The project management system should be available via a computer network connection. Develop and maintain a quality assessment program that includes measures of both performance in moving toward agreed upon quantitative goals and in customer satisfaction with products delivered to the user, including citation indices for peer-reviewed papers and trend data of quality assessment parameters of products. This function also includes planning and tracking support, as well as producing, integrating, editing, maintaining and updating electronic and published versions of documents. Attend and make presentations at meetings and conferences, both within and outside of NASA. All documentation, data, databases, and other pertinent deliverables should be accessible in electronic form.

Plan the agenda, documentation, and computer/software services that will be provided at regional, national, and international workshops, conferences, and symposia; and shall act as executive secretary for the meetings, taking minutes and providing auxiliary technical information as requested and required.

Through the use of appropriate databases, document archives, data products, reliability and quality assurance, configuration control, standard safety procedures, and program and resource analysis tools, provide support for major Laboratory programs. Meetings will be held at specified intervals with the ATRs and COTRs, and reports issued, to assure adequate transfer of information.

0.3. Technical Requirements

This contract complies with the following Section 508 Electronic Information Technology Accessibility Standards: Technical Standard 1194.21, entitled “Software applications and operating systems”, which is applicable for any system upgrades or new requirements; Technical Standard 1194.22, entitled “Web-based intranet and internet information and applications”, which is applicable for any system upgrades or new requirements.

0.4 Acronyms

ACMR	-Airborne C-Band Microwave Radiometer
AESMIR	-Airborne Earth Science Microwave Imaging Radiometer
AJISAI	-Japanese Laser Retroreflector Satellite
AMD	-Angular Momentum Desaturation
AQUA	-EOS satellite for studying Earth’s water cycle
ASCII	-American Standard Code For Information Exchange
ATLAS	Data receiver associated with ICESat-2
ATM	-Airborne Topographic Mapper
ATR	-Assistant Technical Representative
AURA	-EOS satellite for studying atmospheric trace gases
BIH TABLES	-Earth Orientation And Solar And Magnetic Flux Tables
C	-Programming language
CARBON 3D	-spaceborne multi-beam laser altimeter based on VCL design
C3DC	-Carbon 3D Data Center
CD	-Compact Disk
CDDIS	-Crustal Dynamics Data Information System
CD-ROM	-Compact Disk Read-Only Memory
CDP	-Crustal Dynamics Project
CO	-Contract Officer
CHAMP	-CHAllenging Minisatellite Payload
CNES	-Centre Nationale D’Estudes Spatiales

CSR	-Center for Space Research, University of Texas
COSMIC	-Constellation Observing System for Meteorology, Ionosphere, and Climate
COTR	-Contracting Officer's Technical Representative
CPU	Central Processing Unit
CRYOSAT	-ESA ice radar altimetry mission
DESDynI	-Deformation, Ecosystem Structure and Dynamics of Ice mission
DHF	-Data Holding File
DORIS	-Doppler ORbitography Integrated by Satellite
DSN	-Deep Space Network
ECHO	-EOS Clearinghouse
EGM96	-Earth Gravity Model 96
EMS	ESDIS Metrics System
EOS	Earth Observing System
EOS-ALT	-Earth Observing System Altimeter
EOSDIS	-Earth Observation System Data and Information System
ERODYN	-Error Analysis Program
ERS	-European Research Satellite
FORTRAN	- FORmula TRANslation computer programming language
FTP	-File Transfer Protocol
GCMD	-Global Change Master Directory
GEODYN	-Geodynamics Orbit And Geodetic Parameter Estimation System
GEOSAT	-Altimeter Satellite

GEOS-3	-NASA Altimeter satellite
GFO	-GEOSAT Follow-On (US Navy altimeter mission)
GGAO	-Goddard Geophysical and Astronomical Observatory
GGOS	-Global Geodetic Observing System
GLAS	-Geoscience Laser Altimeter System
GLONASS	-GLObal Navigation Satellite System
GLOW	-Goddard Lidar Observatory for Winds
GM	-gravitational constant times mass
GMT	-General Mapping Tools
GNSS	-Global Navigation Satellite System
GOCE	- Gravity Ocean Climate Experiment
GPP	-GEODYN Pre-Processor/Text Editing Program
GPS	-Global Positioning System
GPSRO	-GPS Radio Occultation
GRACE	-Gravity Recovery And Climate Experiment
GSAC	-GPS Seamless Archive Center
GSDPS	-Geodetic Satellite Data Processing System
GSFC	-Goddard Space Flight Center
HAP	-Harmonic Analysis Program
HARLIE	-Holographic Airborne Rotating Lidar Instrument Experiment
HGA	-High Gain Antenna
HP	-Hewlett Packard

IAG	-International Association of Geodesy
IBM	-International Business Machines
ICESat	-Ice Cloud and land Elevation Satellite
IDS	-International DORIS Service
IERS	-International Earth Rotation Service
IGDR	-Interim Geophysical Data Records
IGS	-International GNSS Service
ILRS	-International Laser Ranging Service
ISF	-Instrument Support Facility
IVS	-International VLBI Service for Geodesy and Astrometry
IT	-Information Technology
JPL	-Jet Propulsion Laboratory
LAGEOS	-Laser Geodynamic Satellite
LAN	-Local Area Network
LARES	-Laser Relativity Satellite
LARETS	Russian Laser Retro-reflector Satellite
LEO	Low Earth Orbit
LRO	-Lunar Reconnaissance Orbiter
LINUX	-Operating system
LLR	-Lunar Laser Ranging
LRAD	-L-band Radiometer
LVIS	-Laser Vegetation Imaging Sensor
MAVEN	Mars Atmosphere and Volatile Evolution mission

MB	-Megabyte
MESSENGER	Mercury spacecraft
MGS	-Mars Global Surveyor
MOE	-Medium Precision Orbit Ephemeris
MOLA	-Mars Global Surveyor Laser Altimeter
MPL	-Micro Pulse Lidar
MRO	-Mars Reconnaissance Orbiter
MySQL	-A Relational Database Management System
NASA	-National Aeronautics And Space Administration
NCCS	-NASA Center For Computational Sciences
NFS	-Network File System
NGS	-National Geodetic Survey
NGSLR	Next Generation Satellite Laser Ranging
NILU	-Norwegian Institute for Air Research
NOAA	-National Oceanic and Atmospheric Administration
NRAO	-National Radio Astronomy Observatory
NSCAT	-NASA Scatterometer
ODYSSEY	-Mars spacecraft
ORAN	-Orbit Analysis Program
OS	-Operating System
PAD	-Precision Altitude Determination
PC	-Personal Computer

PDS	-Planetary Data System
PERL	-Practical Extraction and Report Language
PGSLA	-Precision Geolocation System for Laser Altimetry
PI	-Principal Investigator
POCM4-B	-Parallel Ocean Climate Model 4-B
POD	-Precision Orbit Determination
POE	-Precision Orbit Ephemeris
PRARE	-Precise Range And Range-rate Equipment
RDBMS	-Relational Data Base Management System
RFP	-Request for Proposals
RINEX	-Receiver Independent EXchange
SAGE	-Stratospheric Aerosol and Gas Experiment
SAR	-Synthetic Aperture Radar
SCF	-Science Computing Facility
SELENE	-Japanese lunar mission
SENH	-Solid Earth and Natural Hazards Program
SINEX	-Solution INdependent EXchange format
SLA	-Shuttle Laser Altimeter
SLICER	-Scanning Lidar Imager
SLR	-Satellite Laser Ranging
SOLVE	-least squares normal equation solution software
SOP	-Standard Operating Procedure
SOW	-Statement of Work

SRL	-Scanning Raman Lidar
SRTM	-Shuttle Radar Topographic Mission
STARLETTE	-French Laser Retroreflector Satellite
STELLA	-French SLR Retroreflector Satellite in orbit since 1994
SWOT	-Surface Water Ocean Topography mission
TBD	-To Be Determined
TCP/IP	-Transmission Control Protocol/Internet Protocol
TDRSS	-Tracking And Data Relay Satellite System
TOPEX/Poseidon	US/French Ocean Topography Experiment satellite
TRF	-Terrestrial reference frame
TRMM	-Tropical Rainfall Measuring Mission (TDRSS tracked spacecraft)
UAIRP	-Upper Air Instrumentation Research Project
UNIX	-Operating System
US, USA	-United States, United States of America
USDA	-United States Department of Agriculture
VCL	-Vegetation Canopy Lidar
VLBI	-Very Long Baseline Interferometry
WFF	-Wallops Flight Facility
WWW	-World Wide Web
XBT	-Expendable Bathytheromograph
XTE	-X-Ray Timing Explorer spacecraft.

1. GEODYNAMIC, GEOMAGNETIC, AND PLANETARY STUDIES

1.1. Earth Gravity Field

Background:

The gravity field research at GSFC can be divided into two areas: (1) improvement of the model for the static gravity field including the geoid, and (2) measurement of the time variations of the gravity field due to both tidal forces as well as variations caused by non-tidal mass redistribution in the atmosphere, hydrosphere, cryosphere and solid Earth. In the coming decade, the new data for gravity models will come predominantly from missions such as CHAMP, GRACE, GOCE, and GRACE-follow-on. The satellite-only geopotential models may be tailored to specific missions with the addition of satellite tracking of certain satellites (e.g., SLR tracking of Starlette and Stella, DORIS tracking of CryoSat and TOPEX, SLR, DORIS, altimeter crossover measurements for satellites such as GFO, Envisat, ICESat and Jason, GPS data to orbiting LEO satellites, as well as tracking from low-inclination satellites provided in the past by TDRSS). The time-varying geopotential will be determined independently from missions such as GRACE, GRACE-follow-on, and CHAMP, and in addition from the suite of Earth satellites that have been tracked over the past thirty years. Traditionally satellite tracking data has constrained the long-wavelengths of the geopotential, and the altimetry and surface gravity have provided the resolution of the high degree/short wavelength information. With GRACE, the resolution is dramatically improved, however the use of altimetry and surface gravimetry information will still be necessary to obtain the highest resolution models. A significant challenge will be the improvement of the geophysical models that allow us to fully exploit the GRACE data and develop solutions to the time-varying geopotential that fully realize the goals of the mission.

The new generation of geopotential missions relies on the use of precision accelerometers to model the non-conservative forces. The performance of the accelerometers and the techniques used to analyze these data have a critical bearing on the quality of both the static and time-varying solutions developed from these new geopotential missions.

Technical Requirements

The contractor shall:

1. Develop solutions to the static and time-varying geopotential using the available satellite data with a resolution that is commensurate with the sensitivity of the data.

2. Develop improved geophysical models that allows us to forward model geophysical processes that might alias into solutions for temporal gravity recovery and aid us in interpreting of the scientific results.

3. Process surface gravity measurements for inclusion in the gravity models. Incorporate both terrestrial gravity data and marine gravimetry.

4. Develop and test alternate methods for representing the gravity fields (spherical harmonics, gravity anomaly blocks, etc.)

5. Develop high- resolution gravity models (to spherical harmonic degree 360 or higher).

6. Perform data analysis for CHAMP and GRACE and perform mission analysis for GRACE-follow-on. Analyze accelerometer data from missions such as CHAMP, and GRACE, bearing in mind the many problems inherent to handling this datatype.

7. Analyze GRACE data using techniques that localize the gravity signal in time and space.

8. Develop gravity field error calibration techniques and realistic error covariance matrices.

9. Implement techniques for validation of gravity models, including orbit tests, GPS/Leveling, comparisons with ocean and ocean model data, or other techniques.

1.2. Planetary Gravity Modeling

<u>Background:</u>

This work involves developing improved modeling and analysis techniques for the determination of the gravity field of the Moon, Venus, Mars, and Mercury using Deep Space Network (DSN) tracking data, data from alternate networks as the USN network, and laser ranging data from Earth stations to spacecraft in orbit around other planetary bodies. The data from the current missions (e.g. Mars Odyssey, and Mars Reconnaissance Orbiter) and future missions (MAVEN) are X Band, but future missions may be X Band, X/Ka Band (X up and Ka down), or dual-frequency (X and Ka Band). It is expected data from historical missions such as Mars Global Surveyor, Magellan, the Pioneer Venus Orbiter, Lunar Prospector, the Lunar Orbiters and the Apollo subsatellites, will continue to contribute to the determination of future gravity models. Most of the historical mission data is S Band, whereas Magellan has a mixture of S and X Band data. The goal of the NASA GRAIL mission is the determination of the gravity of the Moon, using a K Band Ranging System. GRAIL will operate for a nominal mission lifetime of 90 days, and the periapsis altitude will vary from 30-50 km in the equatorial latitudes. Other missions to lunar orbit will involve S band two-way tracking, but may also include one-way X band tracking if they carry an ultrastable oscillator (USO), as on GRAIL. The future missions to other planetary bodies may incorporate new technology, such as one-way laser tracking systems (such as LRO/LR) or two-way laser systems (using a form of a laser transponder), or a relay tracking concept (tracking a low orbit satellite using a high Orbiter as on Kaguya). The solutions for Mars include estimates of the time-varying geopotential of the planet to the extent permitted by the resolution of the data, and may solve for ancillary parameters, such as the planetary orientation, the k_2 Love number, and the density of the thermosphere from satellite drag data obtained from orbit determination analyses. The solutions for Venus may use new data from the ESA Venus Express mission, in addition to historic data from Magellan and the Pioneer Venus Orbiter. Other future Venus Orbiter missions are under consideration at NASA and with other international space agencies. The major challenge for these missions is properly modeling the measurement observable, and deriving an a priori model for the non-gravitational forces that allow the data to be analyzed to the requisite accuracy. Altimeter crossover data from precision altimeters (laser & radar) may also provide an indispensable data type both for orbit determination and gravity field improvement.

Technical requirements

The contractor shall

1. Determine the optimal arc-lengths for analysis of the tracking data from new (or old) missions, taking into account factors such as data distribution, and spacecraft events, such as maneuvers and angular momentum desaturation maneuvers, solar-array hide maneuvers etc.

2. Compare existing atmosphere models for Mars and Venus and recommend improvements.

3. Implement the latest IAU or similar high-precision planetary orientation models in the analysis software for the Moon, Mars, Venus, and Mercury, and other planetary bodies that are the objects of geophysical study.

4. Include altimeter crossovers in the geopotential solutions, if the solutions have satellite altimetry and if these data can be of benefit.

5. Perform ancillary tasks are associated with gravity field parameter estimation, such as data preparation and reformatting for GEODYN, the acquisition of spacecraft telemetry and the generation of quaternions to model the motion of the spacecraft and other appendages in the measurement and force model.

6. Archive Level 1 data (tracking data and ancillary information) and Level 2 data

(derived products such as gravity fields, gravity anomaly and geoid maps, error maps of the geoid and gravity anomalies, gravity field error covariances, and improved spacecraft orbits) with the Planetary Data System (PDS).

7. Perform new mission simulations as needed, for example related to missions to Mars, Mercury, Europa, Ganymede, Callisto, Titan and Enceladus.

1.3. Non-Conservative Force Modeling

Background:

Even in an era where precision geodetic spacecraft such as GRACE and CHAMP are equipped with accelerometers, nonconservative force modeling remains important. To some extent errors in the nonconservative force model, or an *a priori* macromodel can be accommodated by estimation of empirical parameters, or the estimation of a quasi-reduced dynamic orbit. However, not all spacecraft benefit from the continuous tracking (e.g., from GPS) that makes the calculation of a reduced dynamic orbit possible. In this circumstance, in order to prevent aliasing and leakage of model error into the estimates of orbit or geophysical parameters, it is essential to develop the appropriate nonconservative force model. Nonconservative force modeling will be especially important for large ungainly spacecraft that fly at low altitude (e.g., Mars Reconnaissance Orbiter or Envisat) or close to the Sun (e.g., MESSENGER), where we know that tracking will not be continuous.

Technical Requirements

The contractor shall:

1. Develop spacecraft specific attitude models for integration into the GEODYN orbit determination code if existing routines are not applicable.

2. Validate GEODYN attitude models with actual spacecraft quaternion data, provided such telemetry data are available.

3. Investigate and understand the spacecraft material properties and their temporal dependence.

4. Improve and refine physical models for solar radiation pressure, albedo, infrared, thermal imbalance, and drag forces.

5. Improve and refine atmospheric density models.

6. Develop capability to import spacecraft telemetry directly into GEODYN. Produce a generic format in order to accommodate a variety of spacecraft.

7. Support software development required to accomplish these tasks.

1.4. Precision Orbit Determination for Altimetry and Other Satellites

Background:

Satellites that carry a radar or a laser altimeter have stringent requirements to determine the orbit as precisely as possible. The requirement for the Jason series of missions (Jason-1, Jason-2, and the future Jason-3) is 1 cm overall radial orbit error. Over the 14 years of the TOPEX/Poseidon mission, the orbits were determined to a precision of 1.5 to 2.0 cm. A number of factors come into play to determine the ease with which this goal can be met: (1) the fidelity of the force models; (2) the quality and distribution of the tracking data; (3) the stability of the reference frame; (4) the reliability and accuracy of models and strategies for correcting the data for troposphere or ionosphere refraction; (5) the accuracy of data-specific corrections (e.g. phase-windup and antenna phase maps for GPS and GPS-user satellites). In the absence of continuous tracking, altimeter ground track crossovers can serve as a valuable independent data type. In addition, the altimeter crossovers can serve to validate orbit performance and orbit improvements. The ability to compute reduced-dynamic and dynamic orbits with different data types, SLR, DORIS, GPS, and intercompare the resultant orbits, is an essential tool to meet the one cm goal of precise orbit determination. With the Jason-1, Jason-2, Jason-3 and GFO-2 type of mission, there is a strong emphasis on operational oceanography and the rapid delivery of orbit and altimeter products. Strategies need to be developed to deliver medium precision orbits with a suitable accuracy and latency.

Technical Requirements

The contractor shall:

1. Process geodetic tracking data to user altimeter satellites (TOPEX, GFO, Jason-1, Jason-2, Jason-3, ICESat, ICESat-2, DESDyn1, LiveX), using the best possible parameterization, measurement and force modeling.

2. Process SLR, DORIS & GPS data to TOPEX/Poseidon, Jason-1 and Jason-2 to continue the process of orbit refinement, and to deliver suitable products to NASA.

3. Support the Precise Orbit Determination teams (POD teams) for Jason-1 & Jason-2 & Jason-3 and validate and intercompare orbits with external analysis centers, compare analysis strategies with other POD analysis centers.

4. Implement and test new realizations of the terrestrial reference frame, and new

refinements to measurement and force modeling, and reprocess as needed the tracking data to the historical altimeter satellites (GEOSAT, GFO, T/P, Jason-1, Jason-2) and future missions such as Jason-3.

5. Provide summaries of mission tracking for meetings of the International Laser Ranging Service (ILRS), and International DORIS Service (IDS).

6. Recompute coordinates of geodetic tracking stations using altimeter satellite data, and tracking data to other satellites, if analysis shows these coordinates produce high residuals or anomalous results. Adjust macromodel parameters, or satellite attitude parameters as needed and dictated by the data and the processing requirements.

1.5. Terrestrial Reference Frame

Background:

The global and continuous monitoring of sea surface and ice-surface topography, gravity field, and ground motions needs to be conducted in a uniform terrestrial reference frame (TRF). This requires the integration of data from a variety of disciplines and techniques. The primary observations are the data provided by the main geophysical techniques: Satellite Laser Ranging (SLR), the Global Positioning System (GPS), DORIS, and VLBI (Very Long Baseline Interferometry). The different techniques provide complementary information and have different performance in terms of their ability to estimate station position and velocities, Earth orientation, geocenter location and motion, and the reference system scale. The interpretation of the long-term change in sea surface topography (global sea level change) depends on the reference system in which both the altimeter data, and the in-situ data (tide gauges) are accurately expressed.

Technical Requirements

The contractor shall:

1. Obtain the station position and velocity estimates for GPS, SLR, DORIS, and VLBI for at least the period 1990-2010, or where the data have the best accuracy. Obtain similar estimates for the Earth orientation. Intercompare solutions provided by the different geodetic techniques.

2. Incorporate data from satellites that are tracked by multiple geodetic techniques into the determination of the International Terrestrial Reference Frame.

3. Determine the location and motion of the Earth's geocenter as accurately as possible.

4. Estimate the vertical motion of tide gauges from independent in-situ geodetic observations.

5. Implement the latest IERS standards in the GEODYN software.

6. Submit SINEX solutions to the IERS, or its constituent services (ILRS, IGS, IDS, IVS).

1.6. Time-Variable Gravity

Background:

Geodetic satellite data of various types, such as SLR, DORIS, GPS and GRACE contain information about the Earth's gravitational field and its temporal variations. Temporal variations will be solved for, using available data to provide a time series of gravity field variations as far back in time as the data permit. The rationale is to use the available space geodetic data, leveraging improvements in force and measurement modeling derived from the GRACE mission, and improvements in the standards for analysis as defined by the IERS to provide such a time series, which will carry the signatures of mass fluid motions to compare with what has been obtained over the GRACE time period through analysis of GRACE data.

Technical Requirements

The contractor shall

1. Implement model improvements to refine the measurement and force modeling, such as (but not limited to) hydrological loading, atmospheric loading, modeling of troposphere gradients, and azimuthal variations in troposphere corrections.

2. Produce a geocenter time series using the available high-quality SLR and DORIS tracking data.

3. Compare the geocenter model determined from space geodetic techniques, either kinematically or dynamically, with independent predictions from geophysical models.

4. Develop a time series of low-degree spherical harmonic solutions of time-variable gravity (if that is indeed the best basis) from 1993 (or earlier) to the present

5. Compare this spherical harmonic time series with GRACE over the time periods where they overlap.

6. Develop strategies to minimize orbit modeling errors in geocenter solutions, such as mismodelling of radiation pressure.

7. Test and apply new models for GIA (global isostatic adjustment) and assess their impact on the geocenter computation and the development of time-variable gravity solutions.

8. Complete work in a timely manner for scientific meetings and the preparation of scientific peer-reviewed journal articles.

1.7. Geophysical Fluids Influences on Global Geodynamics

Background:

The Contractor shall investigate the influence on Earth's rotation, gravitational field, and seal level changes caused by global phenomena that involve large-scale mass transport in the geophysical fluids.

Technical Requirements

The contractor shall:

1. Acquire global atmospheric, oceanographic and hydrological data sets and use to compute global angular momenta and gravitational coefficients. Compute the effect of geophysical fluid (i.e. atmospheric, oceanographic, and hydrological) mass transport on Earth’s rotation and gravitational field, (the latter via precise orbit determination of geodetic satellites). Numerically integrate global data sets on mainframe computers and/or workstations to generate (i) the global angular momenta (3 components); and (ii) the extra gravitational variations with time (especially low degree and order coefficients); and (iii) geocenter motion (3 components), due to geophysical fluid transports.

2. Analyze the above results and compare them with geodetic observations in statistical numerical analysis. Compare the angular momentum series with geodetic observations of Earth’s rotational variations in universal time and polar motion, which are available from space geodetic techniques of SLR, VLBI, and GNSS. Compare the time-variable gravity coefficient and geocenter motion series with SLR and GNSS observations as well as any available dedicated gravity mission data during the contract period. Study the Earth’s physical properties and dynamic behavior. Present results at scientific meetings and submit for publication in scientific journals.

3. Analyze the above geophysical fluids results to help understand and model the variations of the global sea level on a wide range of spatial and temporal scales. Use ocean altimeter data, in conjunction with in situ data from XBT

and tide gauges, and guided by ocean general circulation models that do or do not assimilate external observational data, to separate the steric effect from the mass effect (the mass effect constitutes the oceanic mass transport as a function of space and time).

1.8. Sea Level and Tides

Background:

The objectives of this task involve the measurement and analysis of global sea level and of oceanic and atmospheric tides. The fundamental measurement types are (a) satellite altimeter data, especially from the TOPEX/Poseidon, Jason-1, and follow-on missions, but also non-NASA missions such as Envisat and GFO, (b) GRACE satellite-to-satellite tracking data, as well as other types of past and future satellite laser ranging data, (c) tide gauge data, (d) barometer data, and (e) other data as deemed appropriate to the study of sea level and tides. The key role of satellite altimetry requires that considerable effort be devoted to the processing, analysis, and calibration of that data and to the merging of data from multiple altimeter missions. Tide gauge data are especially useful for calibrating altimetry; such data are routinely being used to monitor long-term drifts and other errors in Jason data.

Sea level is a crucial component of NASA's Science Focus Area of "Climate Variability and Change." Ocean tide models are required for a multitude of applications throughout the geophysical community. In particular, they are needed by NASA and the geodetic community to support the proper interpretation of GRACE and all satellite altimeter measurements. Atmospheric tide models also support such missions and, of course, have many further geophysical applications.

Technical Requirements

In order of importance, the contractor shall:

1. Develop comprehensive high-quality databases of satellite altimeter data and continually improve and update these databases so that the data may be used in the most demanding sea-level studies. Merge the data from historical, current, and future satellite missions into a well-defined reference frame and with the most consistent and accurate algorithms representing the state-of-the-art. Calibrate the data.

2. Use these altimeter datasets to determine the most accurate space-based estimates of global mean sea level trends in a well-defined terrestrial reference system. Provide research and analysis support to interpret these data and to compare with other (e.g., tide gauge) estimates.

3. Provide research and analysis support to determine tidal parameters from radar altimeter data and from GRACE satellite ranging data and from other data as appropriate.

4. Develop a comprehensive database of historical barometric pressure data to be used in studies of atmospheric tides and other types of atmospheric waves. Ensure consistency in the pressure time series and overcome the multitude of difficulties that are typically encountered in these data. Empirically determine maps of a suite of atmospheric tidal waves when station densities are sufficiently high over a particular region.

1.9. Planetary and Interplanetary Studies

Background:

The task will provide analysis support, including simulations and error analysis studies for planetary and interplanetary missions, such as MESSENGER.

Technical Requirements

The contractor shall:

1. Optimize orbital characteristics and spatial and temporal data density to help satisfy the scientific objectives of each mission. Simulated data shall be generated and used in GEODYN to form normal equations for all relevant parameters. The SOLVE system shall be employed to manipulate and invert the normal equations to test parameter estimability and sensitivity.

2. Provide reports for presentations and publications as required.

1.10. Geomagnetic Infrastructure Support

Background:

The contractor shall provide geomagnetic infrastructure support in the areas of Earth and planetary magnetic field studies, especially core, crustal, oceanic and external field modeling, and magnetic field mission support. Work includes extraction of improved crustal magnetic anomaly fields and investigation of the sources of the anomalies, comparison of models for magnetic fields on different planets, mission development and mission support activities. Work involves travel to working group meetings, presentation of results at national and international scientific conferences, and publication of results.

Technical Requirements

The contractor shall:

1. Develop, maintain, modify as needed, and utilize reduction and analysis programs for processing, interpreting and modeling magnetic field data especially on regional scales.

2. As member of mission science teams, support spacecraft studies of magnetic fields of Mercury and other planetary bodies.

3. Develop as needed algorithms for analysis of geophysical, geological, topographic and remote sensing data for investigation of Earth and planetary crustal models.

4. Work with university and other agency partners in development of future flight mission opportunities.

5. Cooperate in the development of new magnetic field missions. Support mission simulation studies.

6. Present and publish results.

1.11. Vertical Station Positions

Background:

Experiments will be conducted to determine the vertical component of Satellite Laser Ranging (SLR) stations to help improve the measurement of global sea level. The results will be compared with measurements from sites occupied by other space geodetic instruments.

Technical Requirements

The contractor shall:

1. Use available SLR observations to characterize regional vertical deformation fields. Experiments will focus on the areas of post-glacial rebound in the Laurentide and Fenno-Scandian regions. The contractor shall also compare and validate SLR observations from sites occupied by VLBI, GNSS, DORIS and PRARE systems. The station positions and their velocities determined by each technology shall be compared to those derived by other analysis centers, and the results analyzed for systematic differences in scale. The station

positions derived from the analyses shall be compared by combining the station position information with the local survey ties obtained from the Crustal Dynamics Data Information System (CDDIS). The analysis shall be conducted using the GEODYN orbit and data reduction system. SLR data from LAGEOS-1 and -2 shall be routinely analyzed in arc lengths of several days, but techniques based on arcs of length varying from several minutes to several weeks shall be utilized when data are available from special campaigns. All of the analysis techniques developed in this task shall be optimized and tested for sensitivity to force model errors to minimize their effects on the geodetic results.

1.12. Geodetic Satellite Analysis

Background:

The contractor shall support research in applications of geodetic satellites carrying SLR retroreflectors.

Technical Requirements

The contractor shall:

1. Analyze LAGEOS-1 and LAGEOS-2 observations collected by the global laser ranging network to determine properties of the solid Earth and atmosphere. In particular, estimates of GM (the product of the Earth's mass and the gravitational constant) shall be made at regular intervals from LAGEOS-1 launch in 1976 to the present. Re-analysis of LAGEOS-1 and -2 data shall be conducted with improved force models, and analysis of SLR observations from other retroreflector satellites shall be conducted when they can improve the solution for Earth scale and other geophysical properties.

2. Investigate the long-term evolution of the orbits of geodetic satellites and develop improved models of the satellites' motion. Variations in semimajor axis and eccentricity shall be analyzed to yield improved drag, drag-like, and radiation pressure perturbation models. The analysis of laser ranging observations to these targets for the study of Earth scale shall build on the evolving improvements in instrument accuracy and shall take advantage of the latest developments in gravity, station, and satellite motion modeling. The effect of satellite signature on the results of SLR observations shall be included in the contractor's analysis. Special studies of station and satellite behavior shall be conducted to support current and projected missions and systems, such as NGSLR.

3. Consider the addition of other satellites (Starlette & Stella) to the geodetic analysis to support and improve the determination of the international terrestrial reference frame.

4. Re-analyze the LRA corrections for TOPEX/Poseidon to ascertain if an improved station & configuration-dependent correction model can be developed for T/P, in light of the model and processing improvements that have been made in other arenas of measurement and force modeling.

5. Support Studies to ascertain the optimum locations for a next-generation geodetic network where SLR, DORIS, GNSS and VLBI will be co-located.

1.13 Core geodynamics and origin of geomagnetic and planetary magnetic fields

Background:

Except Venus, all other planets possess or used to possess a magnetic field of internal origin (the intrinsic field). These planetary magnetic fields are believed to be generated and maintained by convective flow in electrically conducting liquid planetary cores (planetary dynamos). Understanding the dynamics of the planetary dynamos is important for interpreting the planetary magnetic fields measured by past missions, and for providing scientific investigations for future missions. It is also important for understanding the properties of the planetary interiors, planetary evolution history, and magnetic impacts on planetary climate. Investigation of core geodynamics includes numerical simulation, assimilation of data and numerical models, and analysis of various geophysical processes embedded in simulation and assimilation results.

Technical Requirements

The contractor shall:

1. Maintain and improve our dynamo simulation and assimilation systems, MoSST and MoSST_DAS, the two models used for key geodynamo and planetary dynamo studies.

2. Maintain and archive all simulation and assimilation data, and develop necessary software for data retrieval.

3. Provide regularly geomagnetic field and geomagnetic secular variation forecasts utilizing current and past geomagnetic observations (e.g. the geomagnetic field models from 1.10)

4. Develop software and algorithms to aid understanding of the implications of dynamo processes to planetary evolution.

5. Interpret via numerical simulation magnetic anomalies of planetary bodies, including satellites of the planets.

6. Investigate core-mantle interactions and their implications to surface geodynamic observables (time-variable gravity, rotation variation, etc).

7. Use Scientific Visualization techniques to analyze numerical simulation and assimilation solutions.

1.14 Space Geodetic Prototype Station Development

Background:

Space agencies have launched and will continue to launch billions of dollars worth of satellites to make measurements related to Earth's environmental systems. Many of these measurements depend on a highly accurate and stable geodetic reference frame within which to interpret the data and understand trends and the processes of change. Producing a highly accurate reference frame requires establishing a prototype multi-technique Space Geodetic Station at Goddard's Geophysical and Astronomical Observatory (GGAO). This multi-technique station will include next generation SLR and VLBI systems along with GNSS and DORIS systems.

Technical Requirements

The contractor shall:

1. Provide systems, software, optical, mechanical, and electrical engineering support for the SGP Satellite Laser Ranging system which is part of the prototype Global Geodetic Observing System. Operation of the SLR system during engineering testing and during collocation is required. Engineering development includes:
    a. Completion of the NGSLR automation
    b. Support for ground calibration system stability work
    c. Engineering and performance analysis of both ground calibration and satellite ranging
    d. Support in installation of a new laser system
    e. Full analysis of the NGSLR system collocation with MOBLAS-7.
    f. Provide spare operational components, lab space and equipment for hardware diagnostics.
    g. Maintain existing equipment at GGAO.

2. Provide support for VLBI2010 development at GGAO including:
   a. Design and fabrication of VLBI2010 components
   b. Installation of VLBI 2010 equipment
   c. Modification of existing equipment and configurations
   d. Test data acquisition
   e. Participation in VLBI2010 exchange of information.

3. Support the development of automated co-location monitoring for the prototype integrated space geodesy station at GGAO including:
   a. Equipment calibration
   b. Design studies
   c. Surveys
   d. Survey analysis
   e. Software development.

2. ALTIMETRY AND REMOTE SENSING

2.1. ICESat Science Standard Data Products

Background:

The purpose of this task is to provide software and processing related to ICESat for the Cryospheric Sciences Branch of the Hydrospheric and Biospheric Science Laboratory.

Technical Requirements

The contractor shall:

1. Maintain and improve the ICESat routine level 1 and level 2 data processing. Develop the detailed specifications, and follow them when implementing changes to the processing system; knowledge of altimeter data products, usage and algorithms is essential for proper design and implementation of this software. Write test plans for the developed software, and follow them during the integration and software acceptance. Write user guides to all software. Implement the GLAS processing system on computer facilities located at GSFC/Greenbelt, and include software within the GSFC ICESat program to produce the standard products. Support the operation and maintenance of the GLAS Instrument Support Facility (ISF).

2. Analyze GLAS data products, which may include surface-slope/laser-return relationships, laser transmitter/receiver/optics characterizations, atmospheric dynamics, spacecraft attitude estimation, topography, and other studies.

3. Maintain software to minimize reprocessing loads based on reasons for reprocessing such as orbit update, algorithm constant update, or single algorithm change.

4. Insure all software follows a life cycle consisting of six phases: Requirements, Design, Code, Test, Corrections, and Operations.

5. Develop software using modern programming practices and techniques, such as Structured Programming, Data Flow Diagrams, Pseudo-Code, Structured English, Top-down Design and Testing, Prototyping, Peer Reviews, etc. Write software in FORTRAN, C, and other languages as necessary. Develop in a networking environment consisting of Sun and HP computer systems, using the UNIX operating system, along with IBM PC compatible and Macintosh microcomputer systems.

6. Maintain a program library for production and engineering assessment software and related support software. Contain in the library source code, object code, and test data for all the above software. Include the documentation for this software and test data. Develop and implement appropriate configuration control procedures for this program library.

7. Compile and maintain a library of documents relevant to the projects effort. Prepare and produce technical documents in support of the software development activities.

8. Maintain control of the developed software using the Rational Software product ClearCase.

9. Implement, store, and execute all databases, software, analysis results, and final documents on government-owned computer systems.

10. Support branch studies and development related to ICESat-2 and other missions

2.2. Radar Altimeter Performance Analysis

Background:

The purpose of this task is to provide radar altimeter instrument performance analysis for the Cryospheric Sciences Branch of the Hydrospheric and Biospheric Science Laboratory.

Technical Requirements

The contractor shall:

1. Provide a long-term trend analysis of the instrument and the various data products such as height, sea state, and sigma naught and with instrument engineering data to provide calibrations to the technical monitor. Maintain and update multi year databases of performance. Update the website on a regular basis for the user community.

2. Provide software and algorithm maintenance support for the radar altimeter calibration, including the Altimeter Protocode System and the Engineering Assessment Software.

3. Provide algorithm verification elements assigned by the technical monitor, producing project-specific documentation using appropriate style and lay-outs, coordinating reproduction and distribution of documentation, maintaining and updating documentation as required, and providing support for the engineering assessments of the radar altimeter performance which falls under the responsibility of the WFF. Aid the analysis of altimeter data and in developing altimeter engineering assessment reports.

4. Provide support for the system software maintenance related to this research, including general workstations and their associated network (614.W Computer Facility). Provide expertise in UNIX operating systems, specifically centered towards SUN OS and Internet under TCP/IP protocol; The 614.W Computer Facility is composed of UNIX workstations, X-terminals, PCs, and Macintoshes working through Ethernet for sharing resources such as Network File System (NFS) disks and printers. Provide expertise to maintain and upgrade these systems and functions to support projects and to enhance the capability to best perform the related research functions.

5. Provide support of property management for the 614.W Computer Facility, generate shipping documents and property loan agreements, support excess of IT equipment, track IT items sent out for repair, coordinate equipment tagging, acceptance of new IT equipment and processing of IT equipment transfers.

6. Implement, store, and execute all databases, software, analysis results, and final documents on government-owned computer systems.

2.3. Observational Science Sensor Development

Background:

Within the Cryospheric Sciences Branch of the Hydrospheric and Biospheric Science Laboratory., radar and lidar instrumentation is being developed to measure Earth's topography at high precision over water, land, and ice surfaces; to measure the directional spectrum of water waves on Earth's oceans; to sense the spectrum of velocities of elements within precipitation cells in Earth's atmosphere; and to characterize the backscattering properties of Earth's surfaces at microwave frequencies. In addition, active and passive techniques to sense oceanic atmospheric properties are being developed.

A range of engineering and technical expertise is required to support these efforts. The instrumentation under development operates in research aircraft, in the WFF wavetank and rain facilities, or in one of the research laboratories. The performance of the sensing systems can be adversely affected by environmental conditions in these locations. During experimental conditions, the instrumentation must perform reliably. Microwave, optical, and digital engineering expertise is required in design, testing, and experimental evaluation of the radar and lidar systems.

Technical Requirements

The contractor as needed shall:

1. Provide design, fabrication, integration, maintenance, and operation of various instrument systems and test equipment both in the laboratory and during field missions.

2. Provide documentation about instrument hardware and software design, instrument performance, and data analysis as required.

3. Implement, store, and execute all databases, software, analysis results, and final documents on government-owned computer systems.

2.4. Polar Ice Science Using Altimetry

Background:

Satellite altimetry data provides unique information on the topography of Earth's polar ice sheets, surrounding oceans and sea ice, and Mars' polar caps. Of particular interest are the determination of small changes in the elevation of Greenland and Antarctica that may be derived from successive altimetric measurements and interpreted in terms of ice sheet mass balance and changes in climate forcings. Additional activities of interest are the production of topographic maps, elevation profiles, maps of surface slopes and flow directions, ice boundaries, statistical distributions of ice parameters and altimeter performance characteristics, and the development and application of numerical models for analysis and interpretation of observed ice sheet elevation changes, ice dynamics, and mass balance.

The objectives of this work are: (1) to process satellite radar and laser altimetry data acquired over polar ice by the European ERS-1 & 2, TOPEX, Mars Global Surveyor, ICESat/GLAS, CryoSat, and other satellites with radar and laser altimeters such as Envisat and Geosat Follow-on; (2) to develop and apply retracking and other corrections; (3) to develop and evaluate various orbit corrections; (4) to compile and validate level 1 through 4 data sets of ice elevations and other parameters; (5) to maintain a complete library of existing ice altimeter data; (6) to produce data sets in a variety of forms for scientific analysis and transmission to data centers; (7) to assist users in accessing the data sets; and, (8) to create and analyze time series of polar ice elevation changes and interpret the changes in terms of ice dynamics and mass balance.

Technical Requirements

The contractor shall:

1. Develop, modify, and maintain a variety of software for processing of data, merging of input data, applying corrections, plotting, gridding, creating special data bases and catalogs, interactively accessing online data, archiving and backing-up of databases, creating and interactively accessing data on CD-ROMs, and analyzing data for quality validation and scientific studies.

2. Write data formats and develop algorithms for various levels of ICESat/GLAS satellite data processing and data set production, operate the production software, and provide documentation and quality control.

3. Create and maintain records and documentation on the data files and program versions used in various stages of this activity.

4. Operate a system of servers, workstations, X-terminals, PC’s, and data-storage peripherals provided for this work.

5. Calculate and evaluate satellite orbits for altimetry data.

2.5. ICESat/GLAS/CryoSat

Background:

The objectives of this work are to 1) develop algorithms for processing and analysis of satellite laser altimeter and lidar data, 2) develop and/or modify numerical simulators of satellite data, 3) provide systems support for the ICESat/GLAS Science Computing Facility (SCF), 4) analyze and maintain libraries of altimeter data and various satellite and ancillary data sets, 5) assist members of the GLAS Science Team in accessing data and software on the SCF, 6) review and write data formats and develop algorithms for various levels of ICESat/GLAS and CryoSat satellite data, and 7) develop and apply numerical models for analysis and interpretation of observed ice sheet elevation changes.

Technical Requirements

The contractor shall:

1. Develop, modify, and maintain a variety of software for processing of data, merging of input data, applying corrections, plotting, gridding, creating special data bases and catalogs, interactively accessing on-line data, archiving and backing-up of data bases, and analyzing data for quality validation and scientific studies.

2. Operate Goddard GLAS SCF consisting of workstations, X-terminals, output devices, and data-storage peripherals as provided by NASA.

3. Create and maintain a data archive of altimeter data and various satellite and ancillary data sets on polar ice, oceans, and atmospheres including on-line data bases.

4. Create and maintain records and documentation on the data files and program versions used in various stages of this activity.

5. Produce topographic maps, elevation profiles, maps of surface slopes and flow directions, ice boundaries, and statistical distribution of ice parameters and altimeter performance characteristics.

6. Develop and/or modify GLAS data simulators and evaluate performance over various types of ice surfaces and cloud atmospheric parameters.

7. Develop and apply numerical models for analysis and interpretation of observed ice sheet elevation changes, including models of the ice sheet surface mass balance, flow dynamics, and surface energy balance.

2.6. Ice Penetrating Radar

Background:

The focus of this work will be to analyze continuous layers within the ice sheet as detected by the ice-penetrating radio echo sounder. This radar was developed at the

University of Kansas and flown on the NASA P-3 aircraft over most of the Greenland ice sheet.

The primary objectives of this work are to work with and support the PI on the following activities:

1. Identify and trace continuous layers (isochrons) within the ice sheet along each flight line.

2. Determine the 3-dimensional surface of each layer based on interpolation or surface-fitting algorithms.

3. Examining ice core records in order to estimate the date of each surface.

4. Drawing conclusions on the past conditions and flow characteristics of the ice sheet based on the characteristics of these layers.

Technical Requirements

The contractor shall:

1. Maintain and modify existing signal processing software, and develop new software, for the tracing of continuous layers within the ice.

2. Apply that software to all of the available ice sheet radio-echosounder data for Greenland.

3. Develop digital elevation maps for each traceable layer.

4. Compare the depth of each layer to the known age/depth data in the publicly available ice core record from Greenland's Summit to estimate the age of each layer.

2.7. Ice Sheet Satellite Data Analysis

Background:

The focus of this work will be to analyze satellite observations of ice sheet surface and near-surface characteristics to detect changes over the last 20 years. This will involve intercomparisons between different sensors, in situ data and climate model data.

The primary objectives of this work are to work with and support the PI on the following activities:

1. Extract SMMR and SSM/I data sets for Greenland and Antarctica from records on site at GSFC.

2. Extract AVHRR reflectance and temperature records for cloud-free days from the Pathfinder data set at the National Snow and Ice Data Center.

3. Perform intercomparisons between the various data sets, and determine how passive microwave data cab be used to fill in gaps in the AVHRR data during cloudy days.

4. Compare satellite observations and trends to in situ data and climate model data.

Technical Requirements

The contractor shall:

1. Develop, modify, and maintain software for the extraction of data subsets in time and space.

2. Develop a strategy for intercomparison of data sets from different sources (satellite, modeled, and in situ).

3. Perform time series analysis of temperature, reflectance, brightness temperature, and melt.

4. Compare variability and trends of each parameter to modeled climate data and well-known climate indices.

2.8. MOLA Laser Altimetry

Background:

The objectives of this work are to: 1) Develop algorithms for processing and analysis of MOLA (Mars Orbiter Laser Altimeter) data and 2) Develop and apply numerical models of ice dynamics and balance for analysis and interpretation of Mars polar ice caps.

Technical Requirements

The contractor shall:

1. Develop, modify, and maintain a variety of software for processing of data, merging of input data, applying corrections, plotting, gridding, creating special

data bases and catalogs, interactively accessing on-line data, archiving and backing-up of data bases, and analyzing data for quality validation and scientific studies.

2. Create and maintain records and documentation on the data files and program versions used in various stages of this activity.

3. Produce topographic maps, elevation profiles, maps of surface slopes and flow directions, ice boundaries, and statistical distribution of ice parameters and altimeter performance characteristics.

4. Develop and apply numerical models for analysis and interpretation of observed ice cap shape and dynamics, models of the ice mass balance, flow dynamics, and surface energy balance.

2.9. Digital Topography Assessment and Analysis

Background:

This task provides support for the investigation of data sets acquired using laser altimeter and interferometric SAR sensors aboard aircraft and spaceflight platforms for the purpose of improved characterization of land surface topography, vegetation cover and atmospheric conditions affecting the measurements. In particular, inter-comparison of data sets and modeling of instrument performance will be used to assess the quality and accuracy of elevation products. Laser altimeter sources include instrumentation that acquire traditional analog waveforms (e.g. ICESat-1, LVIS), analog discrete returns (e.g. airborne commercial systems) and micropulse photon counting data (e.g. SIMPL and ICESat-2 precursors). Interferometric SAR sources include GEOSAR, SRTM and Tandem-X.

Technical Requirements

The contractor shall:

1. Develop, modify, maintain and apply a variety of software for accessing online data, merging input data, applying corrections, computing derived analysis products, plotting, gridding, generating statistical summaries, creating special data bases, and analyzing data for quality validation and scientific studies.

2. Conduct field experiments as needed involving operation of Global Positioning System receivers to obtain validation data for assessment of the digital elevation data products.

3. Participate in airborne deployments of laser altimeter instrumentation, supporting activities in the field including instrument integration on aircraft, flight operations, and data management and processing during the deployments.

4. Prepare and present results at workshops, project team meetings, and scientific conferences, and prepare manuscripts for publication that document the results.

2.10. Atmospheric Studies

Background:

The Laboratory for Atmospheres of NASA's Goddard Space Flight Center conducts research on temperature, water vapor, ozone, and wind observations, and development efforts of the Upper Air Instrumentation Research Project (UAIRP).

Technical Requirements

The contractor shall:

1. Support for the operation of upper air instruments requiring testing, evaluation, and use, in studies and campaigns, and operation of ground-acquisition equipment. This includes, but is not limited to:

   a. operation, maintenance, and modification of instruments used in ground-based, balloon- and rocket-borne projects associated with temperature, water vapor, ozone, and wind observations, including familiarity with associated calibration standards.

   b. evaluating the performance of existing and new instruments; and assist in the development of their calibration methods and standards, as required.

   c. preparation of instruments and other associated equipment for shipping to field measurement sites, assist in equipment set up, and operation of equipment at field sites, as necessary.

2. Support data analysis and data archiving. This includes:

   a. development, maintenance, and documentation of new and existing software related to UAIRP research studies, procedures, formats, and archiving of the data for use in local applications and for delivery to national, and international data centers. Develop unique formats as required. Ensure that all raw data and basic processing of the measurements are properly saved in separate archives with at least two independent backup files. All reference to documentation includes user instructions, i.e., “run” instructions.

b. analyses (in collaboration with the PI) of atmospheric structure, physics, and dynamics; statistical data analysis; retrieval of satellite data products from specified EOS Science Teams or web-based satellite instrument home pages for the purposes of comparison, analysis and validation with in situ measurements or independent research.

c. analyses (in collaboration with the PI) of measurements from ground- and flight-instrumentation, such as Dobson Spectrophotometer, NILU Irradiance Meter, Micro Pulse Lidar, meteorological rocketsondes, radiosondes, ozonesondes, water vapor sondes, NASA satellites (EOS which includes SAGE, AURA, AQUA, etc), satellites of other agencies (domestic and international) and other special purpose instruments.

d. develop and maintain appropriate web pages for disseminating UAIRP data and information to the NASA community, other US Government agencies, domestic and international community, and the public.

3. Provide visual aids (digital and hard copy) for review and/or presentation at administrative meetings, scientific meetings, conferences, workshops, and any other venue, as requested by the ATR, and provide reports as required.

2.11. Altimetry of Inland Water Bodies

Background:

This project centers on the proven ability of satellite radar altimeters to monitor the variation of surface water height for large inland water bodies. It currently utilizes near-real time altimetric data from the POSEIDON-3 instrument on-board the Jason-2 satellite and archived TOPEX/Poseidon, Jason-1 and GFO data to construct time series of surface water height variations for 75 lakes and reservoirs. A semi-automated data ingestion/analysis system delivers time series products directly delivered to a web site for USDA utilization. Currently, 75 lakes are in the operational database but with the inclusion or ESA mission data in the next phase, this will expand to 500. The tasks of this project are split between NASA/GSFC (USDA funding) and UMD/ESSIC (NASA/Decision Support funding). The following tasks refer to the GSFC SOW.

Technical Requirements

The contractor shall:

1. Perform weekly operational updates to the web-based USDA/CropExplorer reservoir database with the latest near-real time Jason-2 (OSTM) IGDR data and/or other near real time IGDR data (e.g., Envisat) where available.
2. Continue to perform system backup and maintenance on the dedicated BigQuill and Superior computer servers.
3. If the potential for increasing the quantity and/or quality of the original Jason-1 products arises then the contractor will revise the current a) altimeter parameter database b) data processing scheme, and c) lake level products. Ditto for GFO, concentrating on those lakes for which Jason-1 data is missing. The contractor is expected to keep the project informed of any Mission or NASA/GSFC improvements to these data sets that could also lead to enhanced T/P, J-1 or GFO products. The contractor is therefore expected to also i) liaise with UMD on potential revision options, ii) ingest SDR, IGDR or GDR data sets relating to these missions if required.
4. Depending on USDA updated target considerations the contractor will also ingest further GFO, Jason-1, TOPEX/Poseidon, Jason-2 data and create lake products for new targets of interest. These targets will be in addition to the ~75 lakes currently in the scheme. The contractor will use the current (or revised) processing scheme to perform this task liaising with UMD who will provide the target list and track/coastline intersection coordinates.

2.12. Remote Sensing Instrument Development

Background:

This task provides support within the Mesoscale Atmospheric Process Branch of the Laboratory for Atmospheres to a number of active and passive Remote Sensing Instruments including some existing, under development, and contemplated. These instruments range from laboratory prototypes, to ground and aircraft field mission deployable instruments, to spaceborne instruments. In particular, the Mesoscale Atmospheric Process Branch has several optics laboratories for the development of lidar and radar remote sensing technologies, including large holographic optics, lidar scanning and imaging, Doppler lidar, Raman lidar, Doppler radars and microwave radiometers. All of these labs and instruments require varying amounts of technical and engineering support. This task provides that support including safety monitoring.

<u>Technical Requirements</u>

The contractor shall:

1 Support the design, development, fabrication, testing, integration, calibration, application and maintenance of lidar, radar and related remote sensing research equipment and instruments.

2. Provide troubleshooting and repair of lidar, radar and laboratory equipment.

3. Deploy and operate remote sensing instruments and equipment in field missions, ground-based as well as airborne.

4. Support the reduction and analysis of lidar and ancillary measurements from tests and field experiments.

5. Develop and document test procedures on various optical, microwave, and electrical components like lasers, waveguides, holographic lenses, optical interference filters, photon-counting and analog detectors, analog to digital converters, multi-channel scalars, etc.

6. Support deployable remote sensing systems, including the HARLIE, GLOW, ALVICE, MPL, AESMIR, LRAD, ACMR, Scanning Radar Altimeter and others as necessary.

7. Perform the role of safety officer for the associated laboratories and facilities in the Laser Remote Sensing Laboratory, coordinating with the center's safety office to assure these laboratories meet the center's safety standards and documentation.

2.13. Microwave Laboratory Support

Background

This task is to provide electronic and mechanical technician support for the Mesoscale Atmospheric Process Branch of the Laboratory for Atmospheres in the Earth Sciences Division. The contractor will be responsible for the safe operation of the Microwave laboratories in Building 33 and Building 22 and maintenance of the laboratory instruments and equipment, tools including the power machine tools and supplies therein. Specific requests for support and services will be coordinated by the task monitor. The contractor will provide estimated costs and completion schedules for specific support or service requests to the task monitor.

Technical Requirements

Typical requests for technical services for instrumentation include, but are not limited to:

- Development, fabrication, testing, integration, calibration, and maintenance of radar, radiometer, and related remote sensing research equipment and instruments.
- Fabrication of microwave waveguide and other mechanical parts; as well as troubleshooting, repairing and modifying instruments or equipment. The quality of fabrication of mechanical parts or waveguide should be on par with the work of a professional machinist

- Services for experimenters and their instrumentation systems, including packing, shipping of fragile instrumentation systems, and installing and uninstalling of those instruments in the field.
- Instruments may be located on aircraft, ships, spacecraft, trailers, and the ground.
- In addition to maintaining, operating laboratory instruments and ensuring that they are well calibrated the contractor will be expected to have the necessary skills to effectively operate power machine tools including a drill press, milling machine, band saw, and grinder, as well as an acetylene torch.
- The contractor will ensure that the laboratories pass annual and periodic safety reviews with no safety violations, and that Instrument Measuring and Testing Equipment (IMTE) in the laboratories is properly calibrated before use.
- 90% of the specific support and service requests shall be completed by the agreed upon completion date.

3. SOFTWARE DEVELOPMENT AND MAINTENANCE

3.1. GEODYN

Background:

Much of the computational effort of the Planetary Geodynamics Laboratory is based on several pieces of software that have been developed within the Lab (or under its supervision) over a period of years. This includes the GEODYN orbit determination and geodetic parameter estimation program. All programs need professional maintenance (to be kept in good working order through changes in computer operating systems and changes in computing platforms). In addition to that, the GEODYN program shall need continued development to include more capabilities in the areas of orbit dynamics, Earth dynamics and measurement modeling. Some of this type of development may possibly be required for ORAN. ORAN is used for analysis of sensitivity of orbit solutions to various parameters.

The new algorithms developed for and put into GEODYN (and possibly ORAN) shall often be designed starting from a fairly general description of desired capabilities. Many of the capabilities that have proven to be the most useful in GEODYN were conceived of, given a preliminary proof of concept, tested, and final implemented all within a six month period. In some cases a potential capability may not turn out to be useful. Because of this, it is sometimes useful to find quick ways to "patch-in" a limited form of a capability so that testing can be done before further development is approved.

The GEODYN task requires the use and maintenance of programs that support GEODYN. The first of these programs, the GEODYN Pre-Processor (GPP), is used to prepare GEODYN source code for use on various computing platforms (see Technical Requirements below). The other support programs prepare files for input into GEODYN. The "BIH Tables" program converts ASCII information about Earth orientation, solar and magnetic flux into a compact binary file that GEODYN expects. There are two programs which prepare accelerometry data for input into GEODYN. One program prepares an "external acceleration" file. External accelerations are used instead of accelerations computed by certain force models. The other accelerometry program converts the accelerometry into "tracking data" in the GEODYN II tracking data format. There is also a program that prepares global atmospheric loading information for use at tracking stations in GEODYN runs.

The Planetary Geodynamics Laboratory has used GEODYN on a variety of computing platforms. As new cost effective platforms become available, GEODYN and its support programs will be migrated to work on these platforms. The Planetary Geodynamics Laboratory is currently using Apple multi-processor workstations for most applications as well as some legacy Sun-Blade workstations. For some larger applications, GEODYN is run on parallel processor computers (hundreds of processors linked) at the NASA Center for Computational Sciences (NCCS) at the Goddard Space Flight Center. GEODYN has been optimized to generate large systems of least squares normal equations on this platform.

Technical Requirements

The contractor shall:

1. Develop software for GEODYN and ORAN for the various tasks described in this statement of work. “Patch-in" new capabilities when needed and test these capabilities, which may then be further developed depending on the results of tests. Areas of software development may include, but are not limited to:

   a. Upgrading GEODYN’s current laser altimetry capability. As new multi-beam configurations are made available (especially for imaging lidars), there will be new possibilities for observational constraints over areas of overlapping observations.

   b. Upgrading GEODYN’s GPS (Global Positioning System) capability. For most applications GPS data are processed in GEODYN in the form of double differences. GEODYN is currently capable of processing singly differenced and un-differenced data. However, in order to maintain state of the art results, these measurement types require the estimation of many biases parameters and/or the use of a priori clock information. GEODYN would have to be upgraded to accommodate these factors.

2. In the area of maintenance:

a. The GEODYN source code shall be to be maintained in a "Machine Independent Format" so that upon running it through a text editing program, a FORTRAN source can be obtained for the appropriate computing platform. The Planetary Geodynamics Laboratory already has this text editing program (called the GPP) and shall make it available.

b. When a new version of GEODYN is made, the following shall be made available on all of the required computing platforms:

Executable

Machine Independent Source

Object modules required to make the executable

c. Every GEODYN version shall be assigned a version number, which shall appear as part of the standard print out of an execution. It is essential that once a version has been released for general use that the version number shall uniquely identify the executable. Any fix or upgrade to a version requires a new version (and version number).

d. The changes that were made to produce a version from the previous version shall be documented:

In a file maintained on each of the computing platforms.

In a section of comments somewhere in the machine independent source of the version.

e. The naming conventions of executables, objects, source and for the directories where they are kept shall remain consistent.

f. Tracing down problems (debugging). Verifying that problems reported by users are really software bugs and if so, fixing them.

g. Back ups of every released version shall be kept. It is not necessary that they are immediately available, but they must be retrievable.

h. Update GEODYN documentation Volumes III and V as necessary. Volume III documents GEODYN user input control file. Volume V documents all other GEODYN input and output files.

i. Maintain Volume III and Volume V documentation on a web site.

j. Update standard input files required by GEODYN as new data become available. These files include Earth orientation files (polar motion and Earth rotation), solar and magnetic flux files and planetary ephemeris files.

k. GEODYN UNIX tar files shall be created upon request. These tar files shall contain just about everything that would be required to get GEODYN running and tested on a particular platform. All files stored in the tar file shall be in ASCII format. The files shall include:

(i) The GEODYN source code.
(ii) Support files:
- planetary ephemeris in ASCII format
- FORTRAN source to convert the planetary ephemeris to binary.
- BIH/Flux file in ASCII format
- FORTRAN source to convert the polar motion/flux file to binary.

(iii) Benchmarking files:
- Sample gravity field
- Tracking data in ASCII format
- Instruction Card input to GEODYN that will reduce the tracking data
- Script to run GEODYN
- Printed output from GEODYN consistent with all of the above.

l. Respond to problems identified by the users of GEODYN. This is the highest priority. Each problem must checked and, if verified as a legitimate problem, fixed.

3.2. SOLVE and ERODYN

Background:

The SOLVE and ERODYN programs use normal equations and error covariance matrices created by the GEODYN program. SOLVE combines, manipulates and solves sets of normal equations with the goal of estimating parameters of gravity models, tidal models, dynamic ocean topography models, Earth orientation parameters, station coordinates, and other parameters such as spacecraft accelerometer parameters, spacecraft macromodel parameters, and GPS antenna phase maps. ERODYN is an error analysis program that performs consider covariance analysis. It computes and propagates the errors associated with both modeled and unmodeled parameters on least squares solutions.

As with GEODYN, the Planetary Geodynamics Laboratory has used SOLVE on a variety of computing platforms. Also as is the case with GEODYN, as new cost effective platforms become available, SOLVE will be migrated to work on these platforms. The

Planetary Geodynamics Laboratory is currently using Apple multi-processor workstations for most applications as well as some legacy Sun-Blade workstations. For some larger applications, SOLVE needs to run on parallel processor computers (hundreds of processors linked) at the NASA Center for Computational Sciences (NCCS) at the Goddard Space Flight Center. Optimization of SOLVE on this (and possibly on other parallel platforms) may be necessary.

Technical Requirements

The contractor shall:

1. Respond to problems the users of ERODYN and SOLVE identify (this is the highest priority). Check each problem and, if verified as a legitimate problem, fix.

2. Rigorously document differences from previous versions when new versions are released.

3. Make backup copies of all new versions.

4. Ensure that SOLVE is running efficiently on all the computing platforms of the Planetary Geodynamics Laboratory.

3.3. Analysis Software

Background:

Much of the work in the Planetary Geodynamics Laboratory involves running the GEODYN software. Most GEODYN runs require the use of satellite tracking data. These data may be actual data, or in the case of feasibility studies, simulated data. In either case, the data must be prepared for use in GEODYN. In the case of simulated data it is important to create data at realistic observing times with a realistic level of noise. Real data requires preprocessing before use in GEODYN. At the very least, it is necessary to make sure the data is in one of the formats accepted by GEODYN or to convert it into one of those formats. GNSS data requires much effort at the preprocessing stage. GNSS data need to have time tags corrected and cycle slips detected and if possible, repaired. The Planetary Geodynamics Laboratory currently uses the Microcosm GPS preprocessor for this purpose. The preprocessing of data from the Deep Space Network (DSN) also requires a lot of work. Information for a single data point must be gleaned from a number of different files. One set of files may contain information about transmitting frequency (ramping) while another set of files contain information about weather and still other files have the actual observed values. To complicate matters, these files may not be in time order and may contain information, which overlaps with other files. From this, a single file containing all of the information must be created. This file must not contain duplicates and must be in time order.

Many GEODYN runs are production oriented. For example, once a good orbit estimation strategy for a given satellite has been determined, it is often desirable to execute this strategy over a number of orbital arcs. The launching and checking of these runs needs to be automated as much as possible.

After sets of least square normal equations have been generated by GEODYN, the sets are combined and solved by the SOLVE software. Often times it is necessary to try various solutions from the same normal equations by using different data weights or by suppressing certain parameters. In some cases, it may be desirable to use normal equations that have been computed outside of GEODYN. In these cases, it is usually necessary to reformat these normal equations to the GEODYN/SOLVE format.

It is desirable, even necessary, to have GEODYN and SOLVE checked by people other than those who have developed and maintained the code. Before new versions of GEODYN and SOLVE are released, they must first be checked independently on a series of standard bench marks.

Technical Requirements

The contractor shall:

1. Develop software to convert normal equations that have been written by groups outside of the Planetary Geodynamics Laboratory into the SOLVE format.

2. Preprocess of GNSS tracking data. GNSS tracking data and broadcast ephemeris fields which arrive in the RINEX format need to be processed to remove cycle slips, form differenced data and provide starting parameter values for orbit determination.

3. Make GEODYN runs to reduce GNSS data.

4. Simulate data to support various planetary mission feasibility studies. Create “perfect” tracking data assuming a realistic parametrization . These data shall be used to determine how well parameters can be recovered from tracking data. Use altimetry in some cases together with ground tracking data in the simulations.

5. Preprocess ground based tracking and altimetry from planetary orbiters like Lunar Reconnaissance Orbiter (LRO).

6. Make GEODYN orbit determination runs to reduce ground based tracking of orbiters like LRO.

7. Run the standard GEODYN and SOLVE benchmarks when a new version of either software is released. Flag differences from previous version and trace the origin of the differences.

3.4. Laser Altimeter and Geodetic Satellite Data Processing and Analysis

Background:

The main element of this work involves the continued development, modification and maintenance of the Geodetic Satellite Data Processing System (GSDPS), which was formerly known as the Precision Geolocation System for Laser Altimetry (PGSLA). This is a highly automated system built around the GEODYN precision orbit determination and geodetic parameter estimation software system. The GSDPS supports research and analysis associated with geodetic missions such as: ICESat, GRACE and Jason. The system is capable of highly automated Precision Orbit Determination (POD) based on GPS, SLR, DORIS, intersatellite ranging, accelerometry and altimetry, and will also support state-of-the-art spaceborne lidar surface return geolocation and instrument parameter calibration and performance assessment. This is the Planetary Geodynamics Laboratory primary system (with GEODYN as the computational engine) being used to process and analyze ICESat, GRACE and Jason data. The GSDPS is written in several languages to take advantage of their strengths. The second area of this work effort is to provide software and data processing support for the Laser Vegetation Imaging Sensor (LVIS) airborne instrument.

Technical Requirements

The contractor shall:

1. Write the computational elements of GSDPS in FORTRAN 90. Write the management elements in PERL and UNIX shell scripts. Write the visualization elements in UNIX shell scripts and GMT. Professionally maintain and develop the software to work on the widest range of standard UNIX workstations including, but not limited to, SUN OS, HP OS, Mac OS 10.3.X.

2. Develop new processing and analysis algorithms and utilities, and implement these new capabilities in the most flexible and efficient manner.

3. Develop new system capabilities from design to implementation and testing.

4. Develop new processing and analysis capabilities to address future Earth and planetary missions.

5. Test and evaluate new software elements along with new data.

6. Manage the routine processing, re-processing and analysis of large quantities (months or even years) of geodetic data from missions such as GRACE, Jason and ICESat. Manage the computational requirements such as CPU and data storage. Maintain data integrity and analysis results.

7. Maintain internal software documentation and continue to provide function documentation through user initialized “man pages”.

8. Maintain software revision control and ensure necessary backups.

9. Provide analysis support and analysis utility software development.

10. Continue to support the development and maintenance of the LVIS airborne laser altimetry processing software on LINUX and Mac OS 10.3.

3.5. Software Development for Ranging, Altimeter and Transponder Experiments and Information Technology (IT) Support to Goddard’s Geophysical and Astronomical Observatory (GGAO)

Background

The contractor shall develop software for instrument control and data taking for ground, aircraft and space based systems in support of NASA’s Laser Remote Sensing Laboratory. This Lab develops new ideas and new missions in Satellite Laser Ranging (SLR), Laser Altimetry, Laser Transponders, and Laser Communications in support of geodynamics and geophysics. Current work includes the completion of the next generation of eye-safe totally automated satellite laser ranging systems (NGSLR) and continued maintenance and upgrade of the software at the 1.2 Meter Telescope Facility. Work is performed at the Goddard Geophysical and Astronomical Observatory (GGAO).

Technical Requirements

The contractor shall:

1. Complete the NGSLR automation software and maintain all software that was developed for NGLSR on this contract and the previous contract, including the LRO-LR operational ranging software.

2. Upgrade the NGSLR software as needed for new missions and new experiments, such as to track aircraft, to range to transponders, and to support laser communications work.

3. Provide documentation for all upgrades made to the software.

4. Provide support to the NGSLR instrument team during system and subsystem level testing, including running the software during night tests.

6. Maintain all the Operational Software for NASA's 1.2 Meter Telescope Facility (which includes Star and Planetary software and Satellite tracking software). Continue the upgrade to the computers and software at the facility including support of new experiments with any new software needed. Provide support to the 1.2 Meter Telescope instrument team during system and subsystem level testing, including night work.

7. Serve as the GGAO Local Area Network (LAN) coordinator for all internet problems and also serve as the coordinator at GGAO for system administration and IT security issues.

8. Provide System Administration for all computers at GGAO that are owned by the Laser Remote Sensing Laboratory including providing security updates and regular backups.

3.6. Satellite Laser Ranging (SLR) Planning and Performance Assessment and International Laser Ranging Service (ILRS) Support

Background

The International Laser Ranging Service (ILRS) is a global network of approximately 40 permanently operating geodetic quality satellite and lunar laser ranging systems in support of more than 20 geodetic, oceanographic, and special purpose satellite missions. NASA/GSFC currently operates and / or provides direct engineering support for seven of these SLR stations.

The Central Bureau is responsible for the maintenance of the ILRS web site and the daily management and coordination of this service. NASA/GSFC is currently responsible for running the Central Bureau.

NASA/GSFC is also developing the next generation of Satellite Laser Ranging systems, called NGSLR. The prototype is at the Goddard Geophysical and Astronomical Observatory (GGAO) and is in the final stages of development and testing. These new SLR systems are expected to be build and deployed around the globe in the coming years.

Technical Requirements

The contractor shall:

1. Provide an analysis of the Normal Point computation for single photon SLR systems using NGSLR and other single photon multi-kilohertz ILRS stations' data and provide a final report with recommendations on the Normal Point computation.

2. Provide performance assessment and support in final checkout of the NGSLR prototype by analysis of the raw ranging data.

3. Provide performance assessment and support in checkout of all new NGSLR systems.

4. Attend and deliver analysis reports at the monthly meetings of the Central Bureau of the ILRS.

5. Participate in the ILRS Analysis Working Group and tiger teams established to handle unique analysis problems.

6. Continuously update the SLR bibliography on the ILRS web site

7. Develop and implement improved features for the ILRS web site.

8. Conduct special assessment of SLR station performance to investigate technical problems at the stations.

9. Contribute to and support the publication of NASA SLR and ILRS reports highlighting the results of SLR analysis activity.

10. Provide science-based recommendations and support to the Global SLR Network.

3.7. ICESAT-2/ATLAS FLIGHT ALGORITHM DEVELOPMENT SUPPORT

Background

The contractor shall participate as a member of the Flight Science Algorithm Development Team for ICESat-2/ATLAS. The Flight Algorithms optimize the ATLAS receiver data collection and the selection of what data is down-linked. These algorithms will be implemented partially in the hardware (FPGAs) and partially in the flight software on ATLAS. The Algorithm Development Team will consist of Laser Remote Sensing Laboratory personnel, flight software team members, and science team members.

Technical Requirements

The contractor shall:

1. Develop a software simulator (using pieces of the GLAS simulator) that correctly models the terrain, the atmosphere, and the ATLAS instrument. Implement the on-board algorithms with as much fidelity as possible to the way they will be implemented in the onboard ATLAS hardware/software system. The simulator should be developed in FORTRAN.

2. Install the 3D terrain modeling front end to the simulator when that is available.

3. Perform a thorough test of the simulator and provide documentation on the testing.

4. Develop a User's and Programmer's Guide for the simulator.

5. Use the simulator to perform preliminary tests of the algorithm during the algorithm development stages, and then to perform a rigorous checkout of the algorithm at a later stage.

6. Support the algorithm development by attending team and sub-system meetings.

4. DATA CENTERS

4.1. Carbon 3D Data Center

Background:

Carbon 3D is a spaceborne multi-beam laser altimeter active remote sensing instrument based on the VCL design and development. Carbon 3D is proposed to launch within the next five years. The principal goal of the Carbon 3D instrument is the characterization of the three-dimensional structure of the Earth with focus on vegetation canopy vertical and horizontal structure. The datasets derived from the Carbon 3D laser altimeter will significantly improve our estimation of the global biomass and carbon stocks, fractional forest cover, forest extent and condition, and provide canopy data needed for improved biodiversity studies. These data will make a unique contribution to our understanding of many environmental issues, including climate change and variability. The exact configuration of the Carbon 3D instrument and mission is still being finalized, but in general the instrument will have at least 3 lasers providing three ground tracks sampling an 8 km wide swath. Each laser is capable of producing ~20 m diameter surface footprints with ~20 m along-track spacing from low altitude (~400 km). The effort here concentrates on the development of the Carbon 3D Data Center (C3DC). The data center will have the sole responsibility of processing the Carbon 3D science data from Level –1 to Level 3 data products, along with data management and distribution. The accuracy of the surface footprint elevations is expected to be at the sub-decimeter level on low-sloping terrain and canopy height measurements will be at the sub-meter level.

Technical Requirements

The contractor shall:

1. Make the C3DC fully capable of processing Level –1 (raw, compressed and packetized instrument science data) data to the final Level 2 (fully geolocated waveforms) and Level 3 (full resolution canopy height grids) data products.

2. Include in the C3DC all processing elements, including: waveform analysis, precision orbit determination (POD) (based on GPS, SLR and altimetry), precision attitude determination (PAD) based on startracker and gyro instrument data, surface return geolocation, canopy height and surface elevation determination, calibration and validation, data gridding and visualization.

3. Include in the development of the C3DC both hardware configuration and software. Investigate new platform options such as Mac OS 10.3.x.

4. Make the C3DC capable of processing and reprocessing science data simultaneously.

5. Support C3DC algorithm maturation and science data validation and calibration. Allow investigators to easily implement new algorithms for testing, calibration and validation.

6. Ensure that the C3DC has sufficient computational bandwidth to process the large volume of science data to be produced during the mission.

7. Ensure that the C3DC has sufficient storage capacity to support significant levels of reprocessing by keeping recent data on line or near-line.

8. Protect the mission data integrity in the areas of security and protection against loss.

9. Manage with script procedures instead of graphical user interfaces to maximize efficiency, data processing and visualization Graphical user

interfaces create excess work when a particular task is repeated. Modify script procedures to address new problems.

10. Make script procedures for processing and visualization elements easily available to science investigators for modification, experimentation and validation. A high level of access to the processing must be easily available to science investigators.

11. Maximize software maintenance, modification efficiency, along and portability using standard programming and visualization languages such as FORTRAN 90, C, PERL, UNIX shell scripting and GMT.

12. Run the C3DC with a high level of quality assurance, configuration management and risk management.

4.2. Crustal Dynamics Data Information System

Background

The contractor shall support the Crustal Dynamics Data Information System (CDDIS), managed by the Solar System Exploration Data Services Office, Code 690.1.

The CDDIS staff is tasked by the geodynamics community to assist investigators with their data requirements. The data services of the CDDIS consist primarily of receiving and archiving geodynamics and geophysics-related data, products, and information on-line and cataloging these files in the CDDIS database. The CDDIS is responsible for the dissemination of these data, products, and information to authorized NASA investigators and international scientists participating in global space geodesy programs.

The CDDIS operationally supports many international programs such as the International GNSS Service (IGS) and its working groups and pilot projects, the International Laser Ranging Service (ILRS), the International VLBI Service for Geodesy and Astrometry (IVS), the International DORIS Service (IDS), the International Earth Rotation and Reference Systems Service (IERS), and the Global Geodetic Observing System (GGOS). The support of these program and projects requires timely availability of data holdings, within minutes to hours of receipt.

A majority of the data processing efforts, including data verification, distribution, reformatting, and special requests, will be performed on the CDDIS Linux and OS X servers. These processes include special programs to read received files, validate contents, summarize their contents, reformat the data if required, and archive the files to the appropriate disk area and backup media (if required). The CDDIS operational on a distributed Dell Linux/Apple Xserve environment.

Technical Requirements

The contractor shall:

1. Provide data, products, and information to the space geodesy user community on a routine (and timely) basis. These files include GNSS (GPS and GLONASS) data, satellite and lunar laser ranging (SLR and LLR) data, VLBI data base experiments, DORIS data, and products derived from these data.

2. Aid users in accessing CDDIS online archive and provide support for special requests.

3. Maintain and verify the CDDIS database using query language and utilities of the MySQL and Oracle database software.

4. Continue development and implementation of recommendations for modifications to CDDIS metadata by coordinating with EOSDIS and ECHO to permit inclusion of CDDIS metadata in ECHO. Review current accepted standards for metadata to align CDDIS metadata with these standards.

5. Develop enhancements to CDDIS web presence by creating tools for searching the metadata extracted from the incoming data and product files processed for the CDDIS online archive. These enhancements should aid both expert and new users in discovering CDDIS data holdings through spatial, temporal, and parameter searches.

6. Develop and implement redesign of the International Laser Ranging Service (ILRS) web presence using NASA standards as appropriate. Populate new design from existing web pages and enhance as needed.

7. Process all GNSS (GPS and GLONASS) data (observation, navigation, meteorological files) received via network transmission, including data compression and decompression where required, data formatting to RINEX if necessary, data archiving to on-line disk areas, quality checking, data summarization, and loading of summary information into CDDIS database. Data must be made available to the user community through automated processing within an hour of receipt for daily data files and five minutes for hourly and high-rate data files. Ensure timely archive of all data sets. Ensure latest version of UNAVCO's teqc software is utilized for data QC and summarization. Generate Data Holdings Files (DHFs) of current GNSS data for the GPS Seamless Archive Center (GSAC) program on a daily basis and also for other GNSS data as required.

8. Process all SLR data (full-rate, normal points) received from cooperating institutions and the NASA SLR support contractor. Merge daily normal point and full-rate SLR data into monthly files. Load summary files into database

9. Process all DORIS data and generate summaries; load summary files into database.

10. Process any new data and products received for archive in CDDIS as required. Provide data quality and summary information for all data processed.

11. Maintain the data archiving and processing software on the Linux servers. Maintain all software used to generate and verify CDDIS data products. Incorporate enhancement software as required. Develop and document any new automated routines to support the timely archiving and distribution of data sets in these environments.

12. Provide programs for the reformatting and analysis of data products.

13. Validate submitted data products. Load data and summary information into the CDDIS MySQL database.

14. Generate regular (e.g., quarterly) reports for CDDIS data management and users describing the data activity of the project.

15. Provide support to space geodesy user community in accessing CDDIS archive (~three requests per week).

16. Distribute selected hardcopy documentation.

17. Document all programs, procedures, and CDDIS system activities. Revise and enhance the CDDIS Standard Operating Procedures (SOP) manual yearly to contain up-to-date instructions for tasks performed by the CDDIS support staff.

18. Apprise CDDIS government staff daily of any problems in data, processing of data, or with the various computer systems accessed by the support staff.